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Reinforcement of Earth Structures with Cast-In-Place Piles in the Expanded Boreholes

Yu. Bagdasarov
NIIOSP, Moscow, Russia

A. Saurin
Foundation Ltd., Lipetsk, Russia

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REINFORCEMENT OF EARTH STRUCTURES WITH CAST-IN-PLACE PILES IN THE EXPANDED BOREHOLES

Bagdasarov Yu.
NIIOSP
Moscow, Russia

Saurin A.
Foundation Ltd.
Lipetsk, Russia

ABSTRACT

This given work has been dedicated to samples of the constructive layouts for simplified rigid rollers, grounds categories as per labour input of the holes to be unreeled, constructive layouts for strengthening ground constructions with cast-in-place piles in the unreeled holes (PUH). A formula for assessment of the distance between PUH is also given here as well as some results of the studies as per compacted areas of the space around piles and improving PUH ground characteristics (ρ_d and E).

During maintenance process the ground constructions (dams, dikes, roadbeds etc.) are subject to various natural/climatic and technogenic factors, which may result in reducing its supporting capabilities, structural strength, stability and reliability for the further service.

One of the methods per reliability recovery related to the ground constructions' maintenance may be presented as reinforcement of the composed grounds with cast-in-place piles in the unreeled holes (PUH). Such strengthening of ground constructions with PUH has been based upon usage of the hole to be unreeled in the natural & artificial grounds so that to transform its constructive characteristics and to establish reinforced massive construction along with required physical & mechanical properties.

The holes for producing PUH are to be made by overhang operating device such as holes' roller with spiral surface via its rotating and forward motion into ground up to the planned depth. Some various types of the holes' rollers are used as follows:

- simplified and rigidly attached rollers on the common shaft;
- complicated and moveable (bearing-type) rollers attached on the common linear shaft;
- complex and moveable rollers of special type on spiral shaft.

Thanks to the work experience gathered by the Foundation Ltd. over the period of twelve years during which some 32,000 holes have been unreeled and the respective studies as per PUH labour input under various technological & geological terms have been also performed showing that the simplified rigid rollers as the most suitable ones in relation to its care & maintenance and economic efficiency. For instance, the overhaul of the simplified rigid roller (Fig. 1) is to be made upon unreeling some 1,200-1,500 running meters of the holes; 60-110 running meters for the complicated and 30-70 running meters for complex rollers respectively.

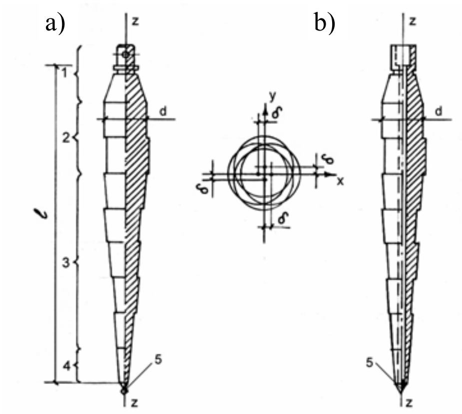

Fig. 1. Constructive layouts of the simplified rigid rollers: a) all-metal, b) all-metal with longitudinal channel and depleted tip; 1 - tail, 2 - forming rollers, 3 - unreeling rollers, 4 - point, 5 - tip, d - forming roller diameter, l - roller length, δ - roller misalignment in relation to its longitudinal axis (Z).

The all-metal rollers (Fig. 1, a) are used for producing vertical, inclined and horizontal PUH in the sand and clay grounds which ensures hole stability against caving and mud flow for some time as well as to fill the hole with such materials as concrete, reinforced concrete, local grounds, natural or artificial crushed stone, crushed stone and ground mixtures (Fig. 2).

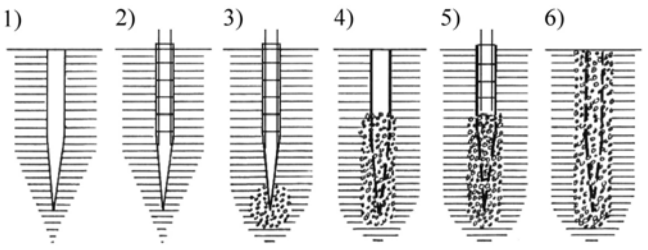

Fig. 2. PUH versions per filling material: 1 - concrete, 2 - reinforced concrete, 3 - reinforced concrete strengthened with crushed stone in the face; 4,5 - combined; 6 - ground (crushed stone, ground and crushed stone, clay, sand, slag).

The rollers with longitudinal channel and depleted tip (Fig. 1, b) are used for producing vertical and inclined PUH within unreliable and water-saturated grounds. The PUH may be produced under such grounds by loading roller up to the planned depth and filling the hole with plastic close-grained concrete or polymerized concrete mixture under pressure from the face towards shaft collar.

The optimal diameter of the simplified rigid roller (d) is equal or less than 30 cm. The usage of the rollers with diameters more than 30 cm may cause reducing the PUH specific carrying capability (F/A) and enhancement specific energetic outlays (W/A), where W - energetic outlays per unreeled hole (kW); F - PUH carrying capability (kN); A - cross-section space of the hole cylindrical part (sq. cm).

While projecting works the unreeled hole diameter must be equal to the diameter of the roller's forming part and to be specified upon results of the tentative unreeling hole under actual ground on construction site.

In the course of the unreeling process during which the ground is displaced into environmental area the following may occur: transformation of the existing structure and conditions and characteristics of the ground construction; forming thickened and thinned areas and establishing conical and cylindrical hole (Fig. 3).

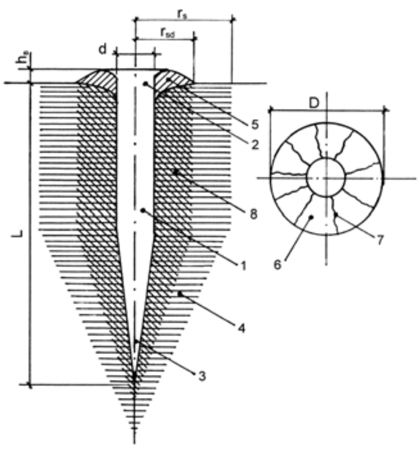

Fig. 3. General parameters of the unreeled hole: 1 - shaft; 2 - collar shaft; 3 - face; 4 - thickened area; 5 - thinned area; 6 - displacement area; 7 - radial fractures; 8 - mostly thickened ground area; d - diameter; L - length; h_B - displacement height; D - displacement diameter; r_s - thickened area radius; r_{sd} - mostly thickened ground area radius.

Consistency of the dry ground within thickened area (ρ_{ds}) may change unevenly depending upon some fey issues as follows: distance to the unreeled hole axis (r); type, condition and thickness of the dry ground (ρ_d) prior to its unreeling process. Fig. 4 shows a plot of ρ_{ds} = f(r) upon unreeled hole with d=25 cm under close-grained sand of average thickness (e=0,73; ρ_d =1,53 g/cub. cm, ρ_s =2,65 g/cub. cm) and semisolid loam (J_L=0,1; ρ_d =1,58 g/cub. cm; ρ_s =2,69 g/cub. cm; e=0,7).

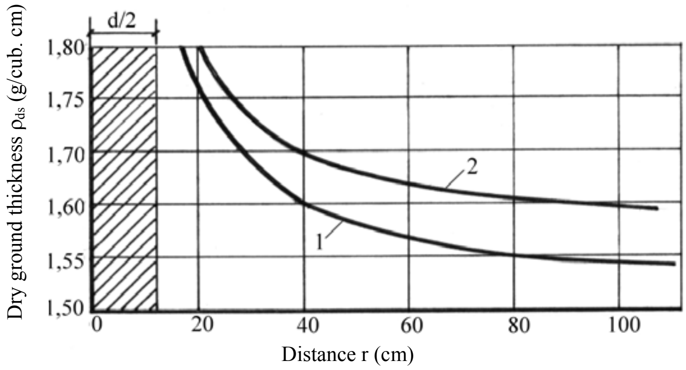

Fig. 4. Common plots of the ρ_{ds} = f(r): close-grained sand (1) and semisolid loam (2) upon unreeling hole with d=25 cm.

It is clear from the plots as above that the mostly thickened ground may occur at the distance of r_{sd} being equal or less than 2,5 d.

The repeated unreeling process of the hole filled with sand may result in enlarged area of the mostly thickened ground (Fig. 5).

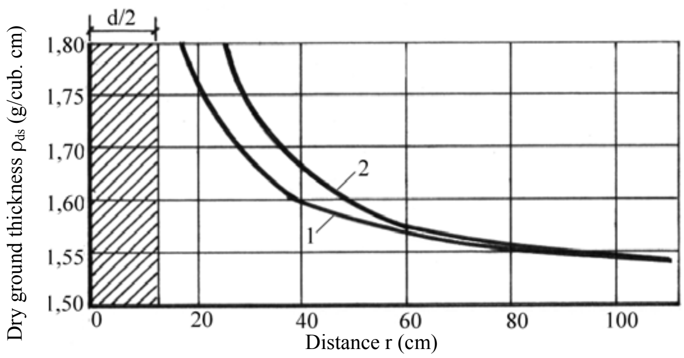

Fig. 5. Plot of ρ_{ds} = f (r): 1 - upon unreeling hole in the close-grained sand (ρ_d = 1,53 g/cub. cm); 2 - upon repeated unreeling hole filled with close-grained sand.

The enlargement of the mostly thickened ground area may cause a superficial ground displacement within collar shaft and thinned area respectively.

The unreeled hole must be filled with relevant material completely (concrete and reinforced concrete PUH) or partially (ground PUH) provided that each portion being thickened under full axial force of the roller unit.

The partial volume (V_p) must be defined depending on relevant type, condition and thickness of the unreeled ground, unreeled hole volume (V) and to be specified upon results of the tentative technological mode as per PUH under ground conditions on construction site. Usually such a partial volume V_p=0,08-1,2 V.

Within uniform ground the distance (b) between parallel PUH must be defined by the following formula:

$$b = 4 \cdot K_s \cdot d \cdot \lg \frac{\rho_s - \rho_{ds}}{\rho_{ds} - \rho_d} \qquad (1)$$

where:
4 - ratio of the imposing thickened areas around piles;
d - pile diameter (cm);
ρ_d - initial dry ground thickness prior to its unreeling process (g/cub. cm);
ρ_{ds} - required dry ground thickness between piles (g/cub. cm);
K_s - ratio of the dry ground thickness being altered between piles ($K_s = \rho_{ds}/\rho_s$);
ρ_s - ground particles thickness (g/cub. cm);
$\lg \frac{\rho_s - \rho_{ds}}{\rho_{ds} - \rho_d}$ - ratio of the ρ_{ds} being altered within thickened area.

The strengthening of ground construction of the PUH must be done accordingly to relevant constructive layout (Fig. 6) with consideration of some issues as follows: technical condition and functional designation of the construction; ground and hydrogeological conditions on site; used materials and technological facilities; working period.

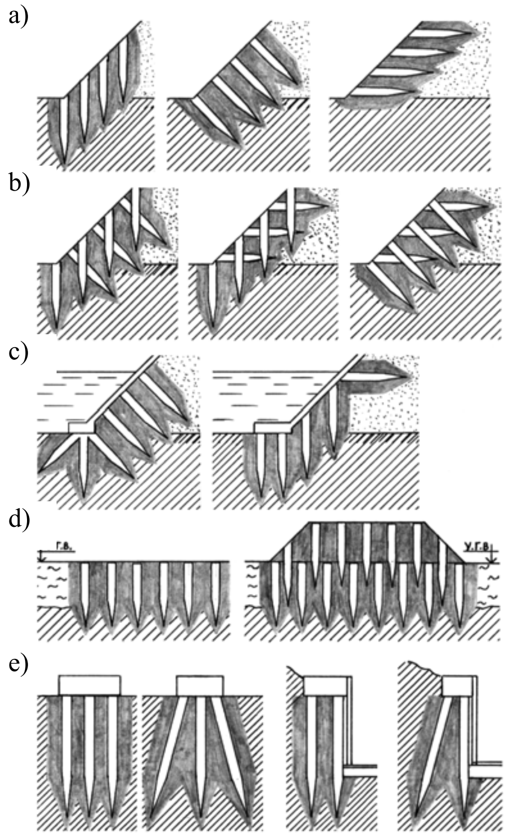

Fig. 6. Samples of the PUH constructive layouts for items as follows:
a, b - strengthening slopes;
c - establishing curtain grouting;
d - transforming constrictive natural and artificial grounds;
e - establishing reinforced bedding of the basement and bulkheads.

The constructive PUH layouts as seen in Fig. 6 create local or complete reinforced massive construction with improved physical & mechanical characteristics and properties within ground constructions.

With reason to esteem actual values of the relevant physical & mechanical properties as per reinforced massive construction some various field-proven methods may be used including complex static probe technology developed by the NIIOSP nm. by Gersevanov (Fig. 7) as well as by using static probe of the massive fragment or any individual supporting construction element as PUH (Fig. 8).

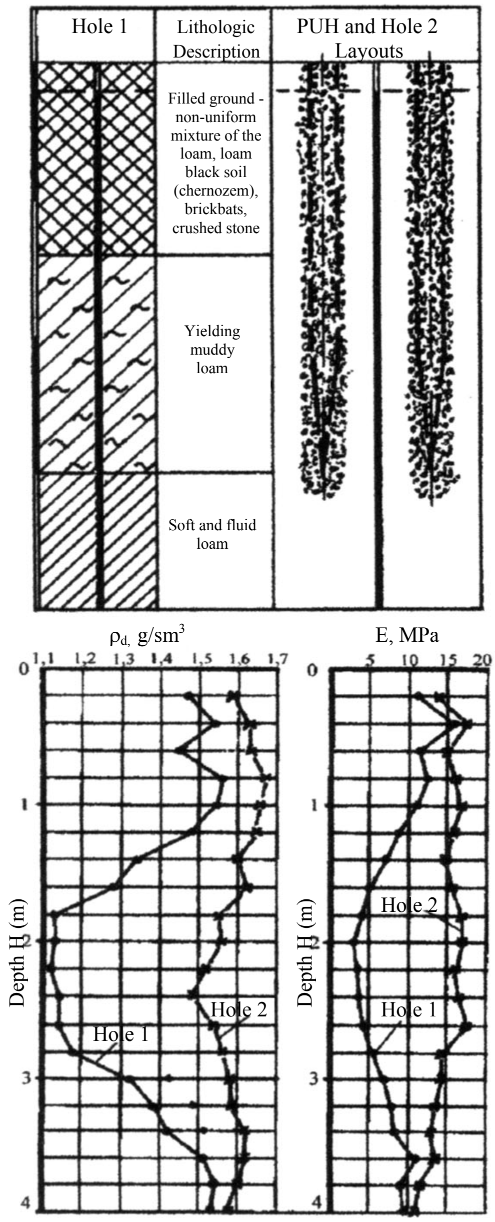

Fig. 7. Results of the studies per basement bedding strengthened by PUH with crushed stone via method of complex static probe: a - geological site location and piles' area layout; b - dry ground thickness (ρ_d) and distortion module (E) per depth: Hole 1 - prior to unreeling holes; Hole 2 - upon establishing PUH with crushed stone.

Fig. 8. Common view of the static probing reinforced massive construction fragment made by vertical PUH with crushed stone within a soft and water-saturated ground.

As one could see from the plots (Fig. 7) of the ρ_d and E values as per depth prior to and upon establishing PUH with crushed stone the values of ρ_d and E have been altered mostly within a soft ground, i.e. yielding muddy loam. These alterations have occurred due to some crushed stone being implemented into loam structure and its interstitial water squeezing and forming artificial massive loam with crushed stone within space between piles. As compared with the initial values the relevant dry loam thickness increased 1,3 times and its distortion module became 3,3 times more respectively.

INFERENCE

1. Under unreeling process of the holes the ground must be displaced into nearby space whereas some thickened area has been formed with radius being equal or less than 4d.
2. Changing of consistency of the dry ground within thickened area (ρ_{ds}) may alter in non-linear manner depending on a distance to the unreeled hole axis (r). The most alterations of ρ_{ds} have occurred at the distance (r_{sd}), which is equal or less than 2,5d.
3. The distance (b) between PUH must be defined accordingly to the required dry ground thickness (ρ_{ds}) between piles.
4. The PUH must be located within ground construction in accordance with some specific layout accounting a degree of thickened areas being imposed between piles.
5. Usage of the vertical, inclined and horizontal PUH with the purpose of strengthening ground construction may allow:

- to eliminate settlement, landslide and boil processes;
- to transform constructive properties of the soft grounds including water-saturated ones;
- to produce reinforced beddings with required characteristics.

REFERENCES

[1987]. *"Construction norms and specifications 2.02.01-83*. Construction beddings. Project norms"*. Stroyizdat, Moscow.

Feklin, V. [1985]. *"Technology of strengthening bedding of the constructions being renovated by using spiral dredge"*. Industrial Construction, No. 8, pp. 30-33.

"Manual on projecting buildings and constructions", *(attached to the construction norms and specifications 2.02.01-83)*.

[2002]. *"Recommendations as per projecting and establishing cast-in-place piles within unreeled holes"*. NIIOSP nm. by Gersevanov, Moscow.